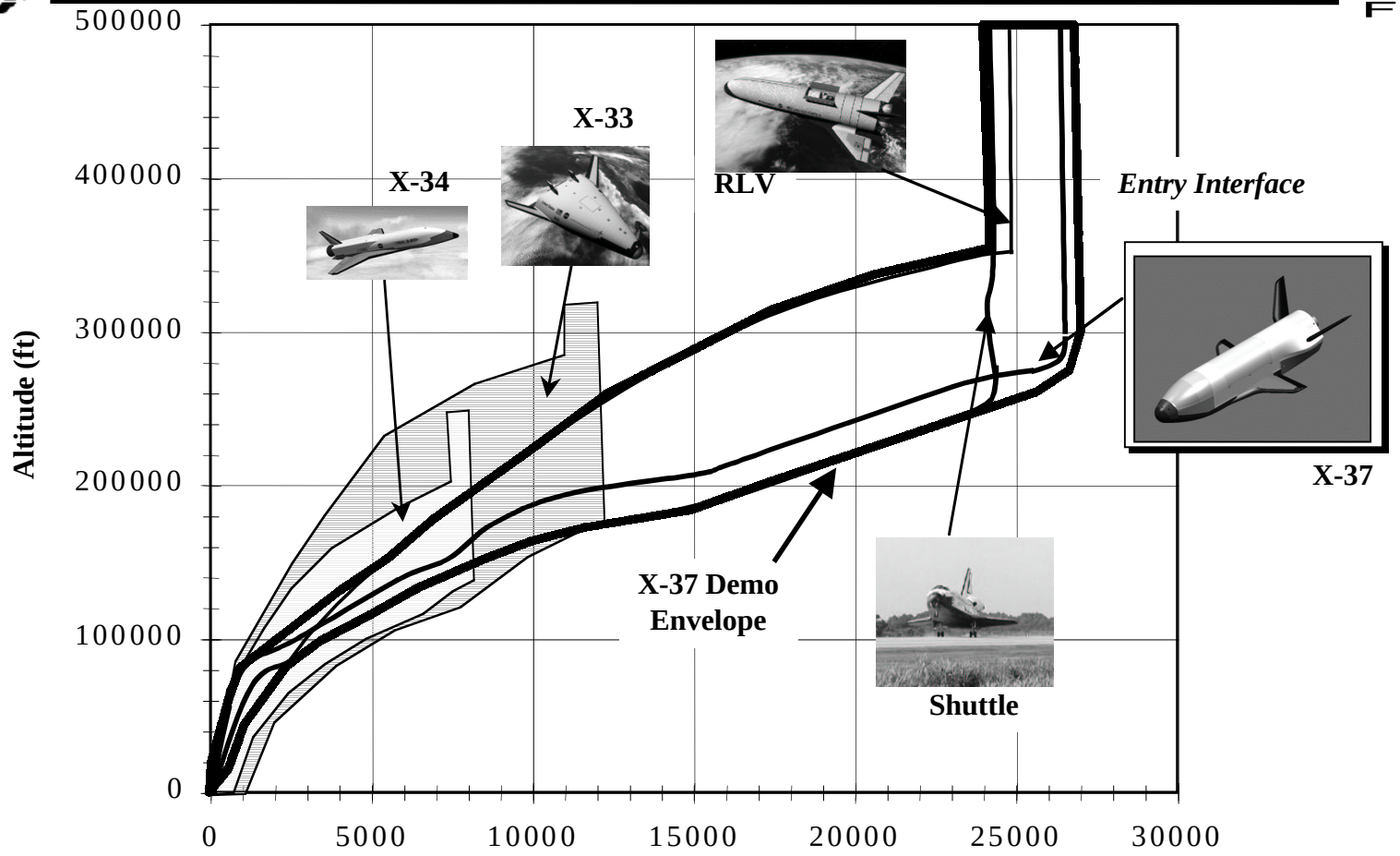
X-40A Flight Test Program

Flight Test Objectives

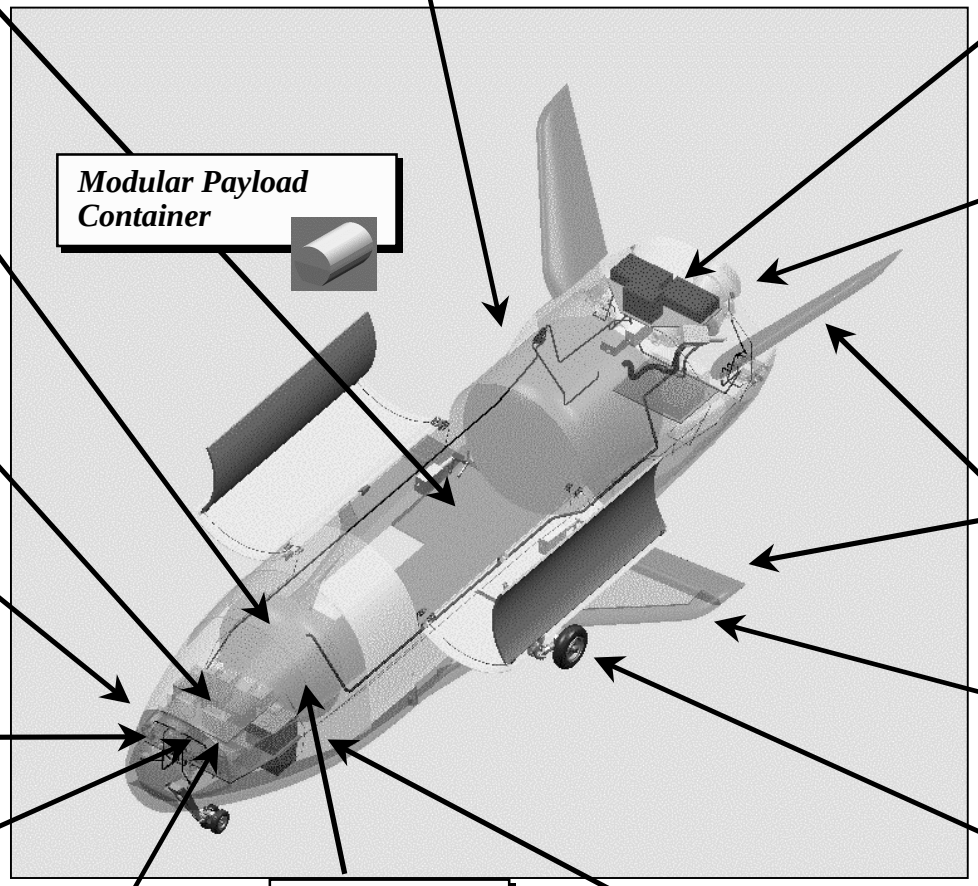
- **Reduce the risk to the X-37 by**
  - Acquiring operating and performance data
  - Approach and landing phases of flight
- **Evaluate the Space Integrated GPS/INS (SIGI) Nav System**
- **Evaluate the Calibrated Air Data System (CADS)**
- **Acquire & Evaluate Vehicle Aerodynamic Characteristic Data**
  - Stability & Control Derivatives
  - Vehicle Base Drag

X-37 Extends the Testbed Envelope to Orbital Capability



- **X-37 Provides Orbital and Re-entry Test Capability**
  - Reentry trajectory can simulate TSTO 2nd stage environment
  - Autonomous operations (maneuver and rendezvous)
  - Long-term on-orbit demonstrations (2-21 days)

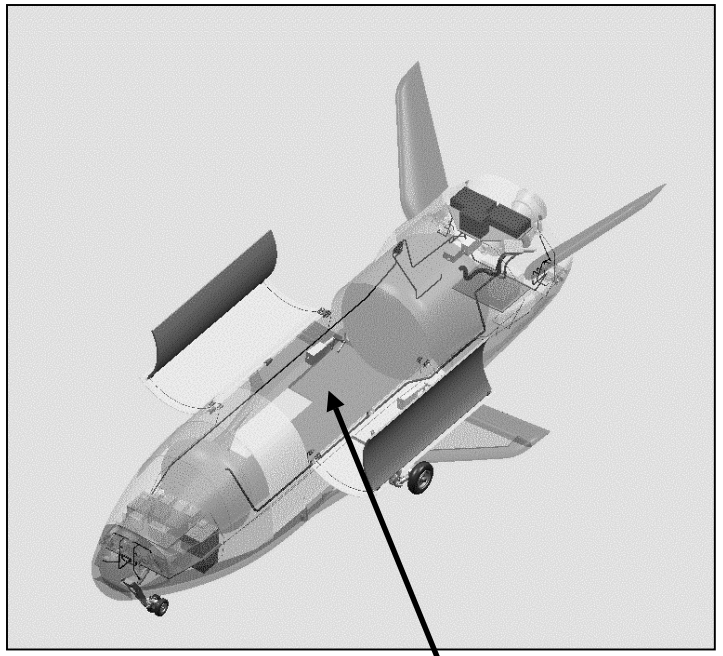
X-37 Modularity Readily Supports Rapid Technology Insertion and Experiments



- ***Payload Experiment Bay***
- ***Replaceable Test Panels (upper & lower body surfaces)***
- ***Adaptable Thrust Structure***
- ***Removable Upper Forward Fuselage Panel***
- ***Modular Payload Container***
- ***Replaceable Main Propulsion System***
- ***Flexible Launch Interfaces***
  - Aircraft
  - ELV
  - Shuttle
- ***Easy Access Avionics Bay Panel***
- ***Replaceable Ruddervators & Flaperons***
- ***Modular Nose Cone***
- ***Upgradable IVHM Subsystem Interfaces***
- ***Modular Wing Leading Edges***
- ***Open Architecture Avionics Design***
- ***Adaptable Flight Instrumentation***
- ***Replaceable Tank***
- ***Upgradable EPS***
- ***Replaceable Landing Gear & Tires***

Key Elements of the X-37 Project

- **Leverage current AF X-40A and Flight Operations Control Center for risk reduction**
- **In parallel build X-37**
  - SMV derived design
  - Orbit capable -- fully reusable
  - Modularized, technology-rich testbed
  - Common, open avionics architecture for flexible payload integration and operation
- **Fly early and often under three-phase flight test program**
  - X-40A / Helicopter (unpowered)
  - X-37 / B-52 (unpowered)
  - X-37 / Reentry (ELV launch)

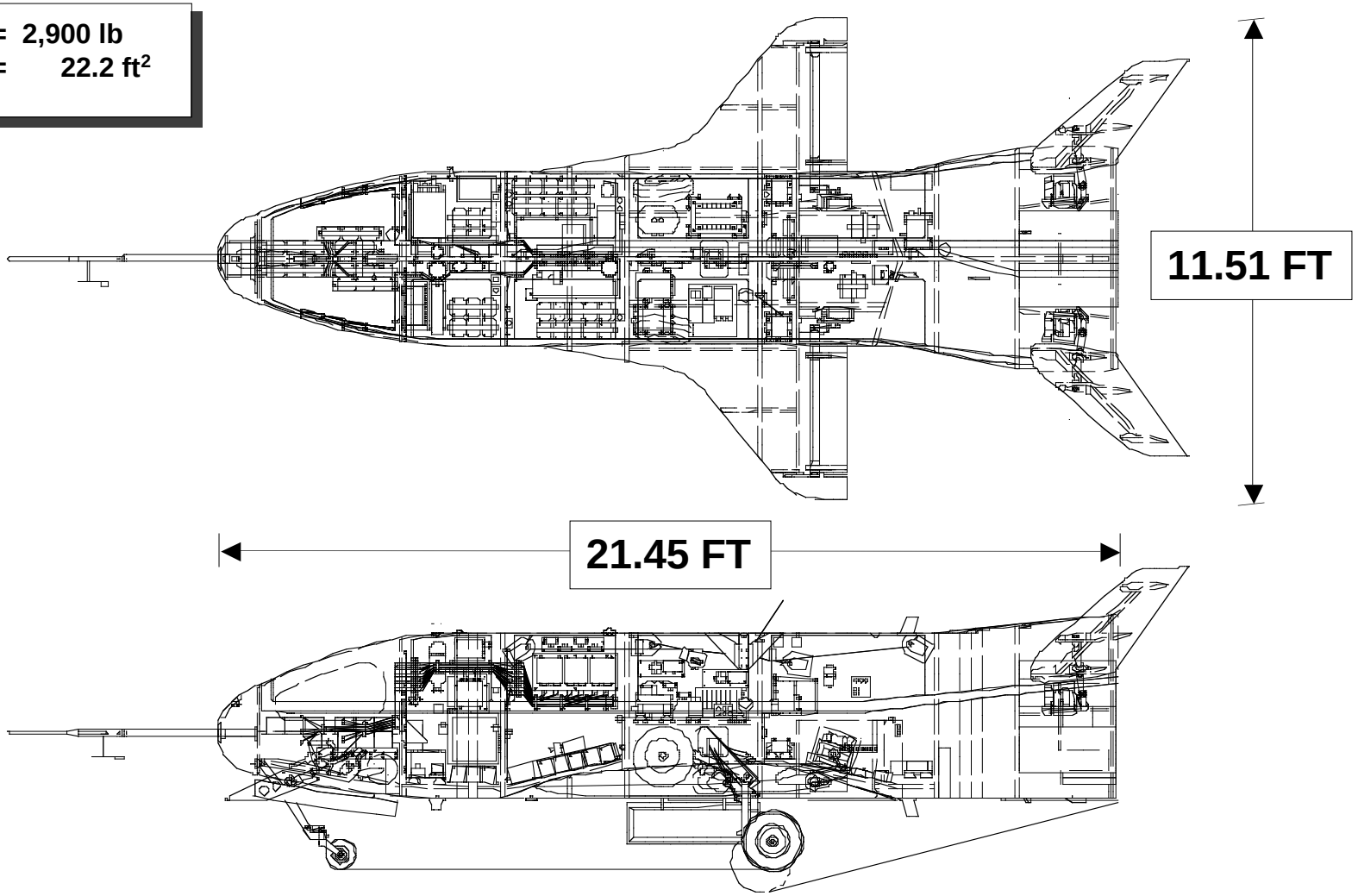


Payload Bay & Support Services Retained for Experiments

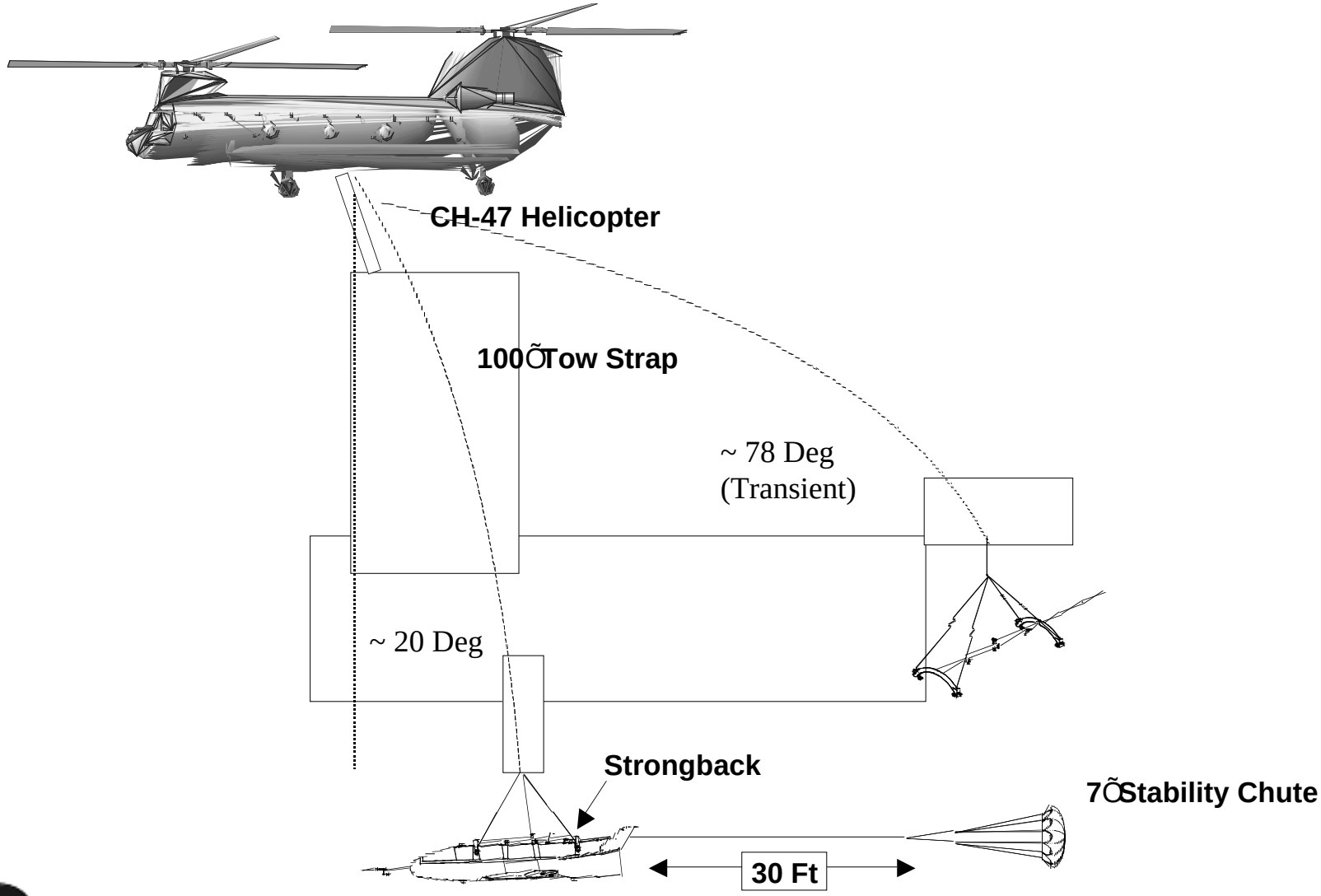
First Free Flight of X-40A Flight Test Vehicle Conducted Successfully on 11 Aug 98

X-40A Vehicle

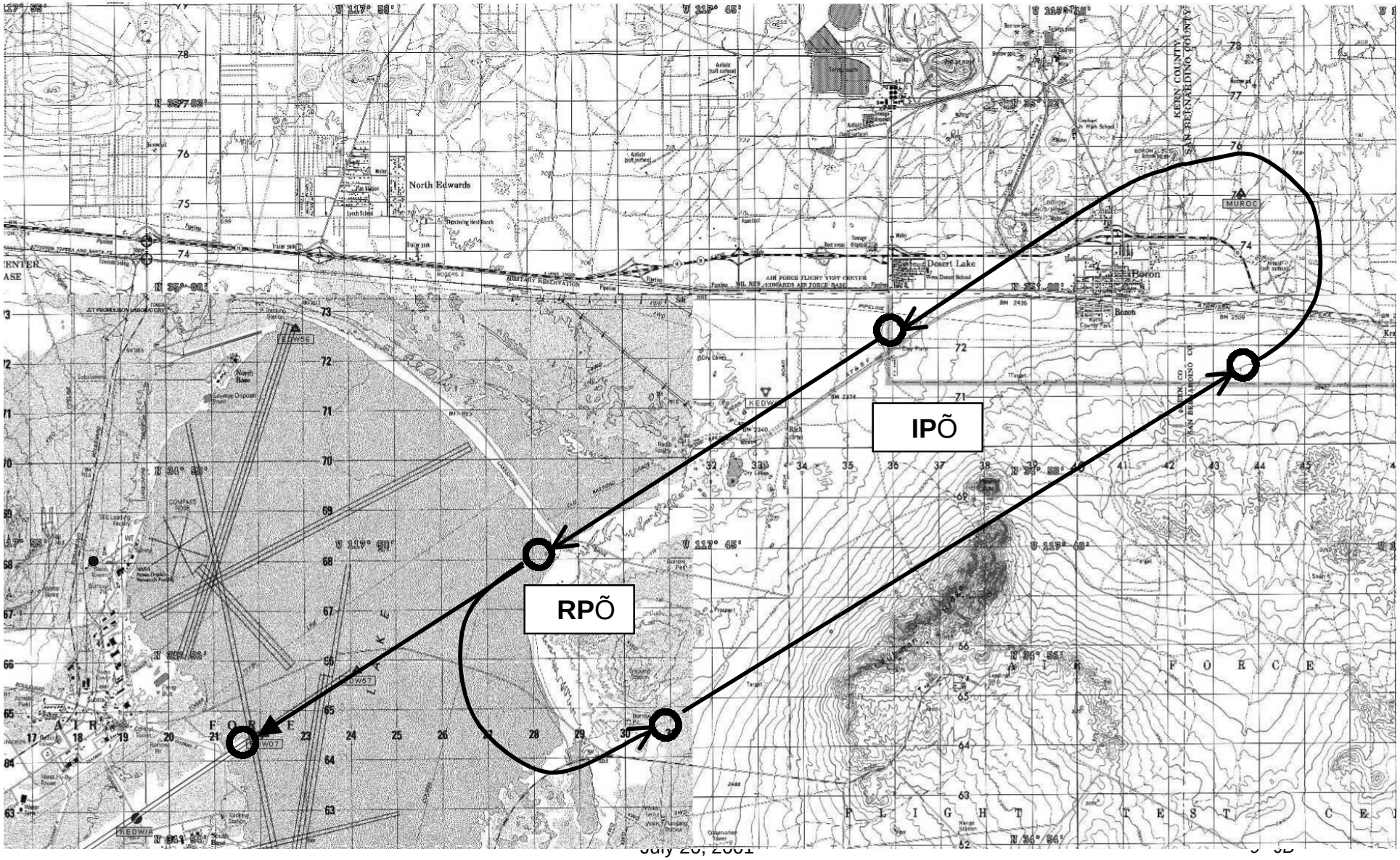
TOGW = 2,900 lb
Planform= 22.2 ft^2



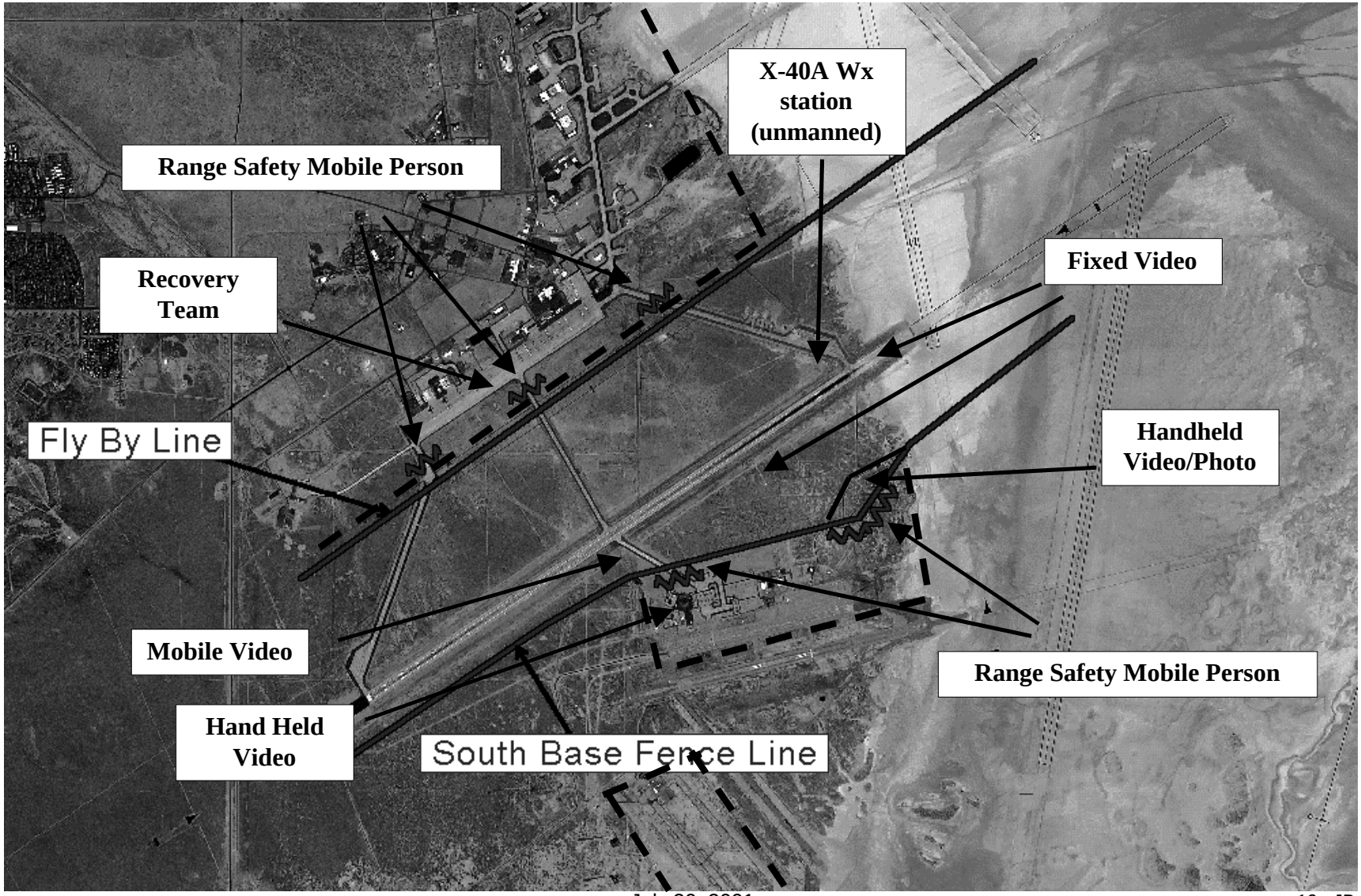
Flight Test Operations



Captive/Free Flight Ground Track

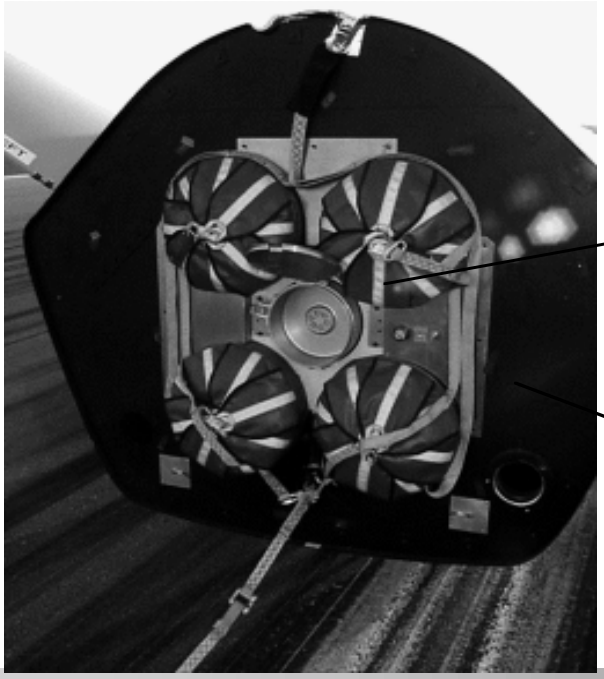


Rwy 22 Layout



FTS/Vehicle Recovery System (VRS)

- FTS - Activated by RSO
  - Single Drogue - deployed by 2400 psi GN2 supply
  - Cancel X-40A Lift -- puts vehicle in nose down attitude
- VRS - Activated by FOCC
  - Uses same FTS Drogue
  - Once enable by RSO and Baro altitude or uplinked command
    - Drogue chute riser cut -- releasing mains

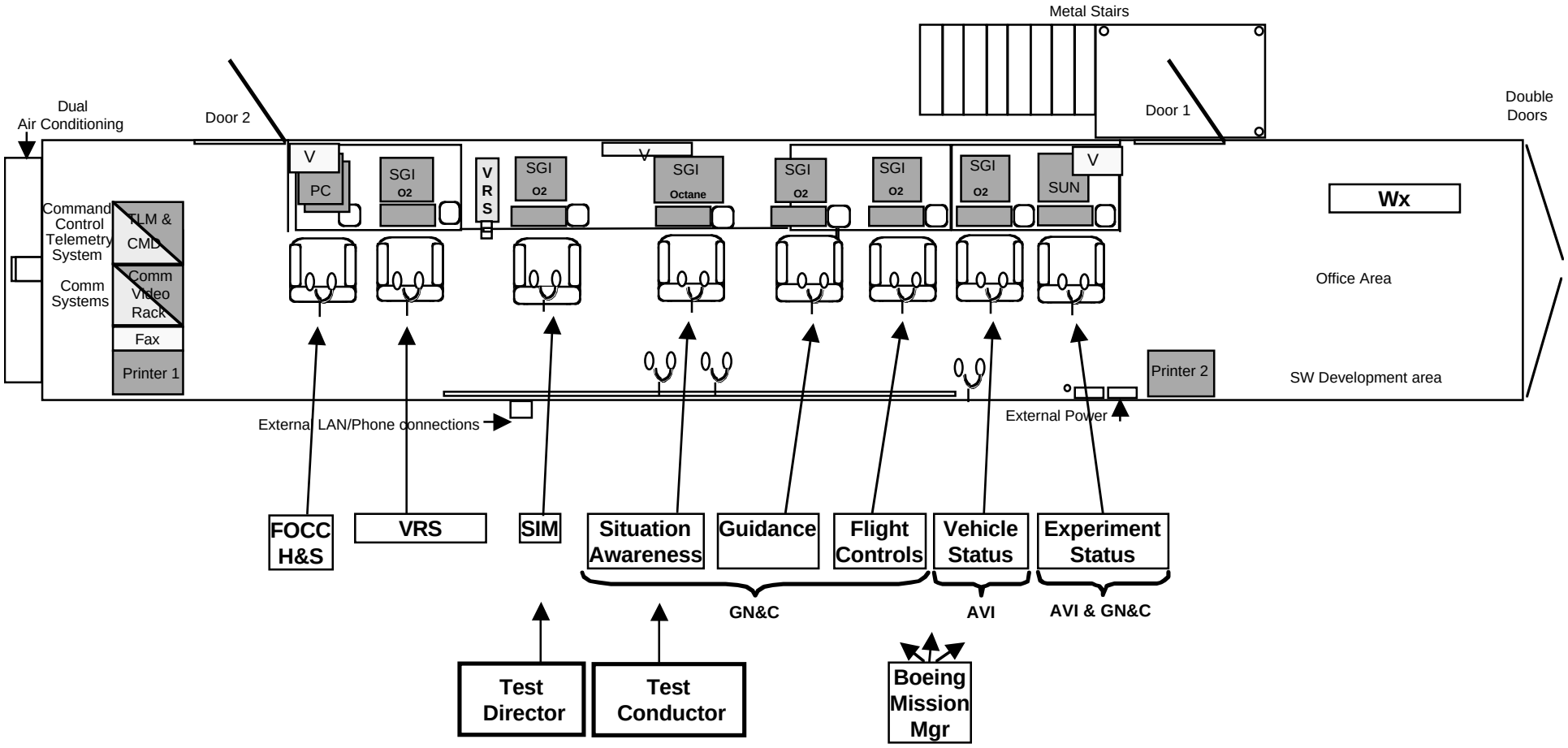


Single VRS/FTS drogue chute
- 13’ diameter ring slot canopy design
- X-31A braking chute heritage
- deployed by >2400 psig GN_2 supply
- shown after deployment during Phase I taxi test

Four main VRS chutes
- 50’ diameter tri-conical design
- target drone heritage
- deployed with drogue chute release

Flight Operations Control Center

- **48’ Trailer, 1 main level: operators co-located (at beginning of Phase 2)**



Communications

	PreFlight	Undock-Flt-Dock	PostFlight
X-40A Ground Crew	X-40 Gnd	**MSN (VHF)**	**X-40 Gnd**
Helo Ground Crew	X-40 Gnd	**MSN (VHF)**	**X-40 Gnd**
CH-47	MSN (VHF)	MSN (VHF)	n/a
	ATC (UHF)	**MSN (UHF)**	n/a
T-34	MSN (VHF)	MSN (VHF)	n/a
	ATC (UHF)	**MSN (UHF)**	n/a
FOCC	X-40 Gnd	X-40 Gnd	X-40 Gnd
	MSN (VHF)	MSN (VHF)	MSN (VHF)
	RSO Net	RSO Net	RSO Net
	RCO Net	RCO Net	RCO Net
	TC	TC	TC
	ATC (UHF)	**MSN (UHF)**	**MSN (UHF)**
MCC - RCO/RSO	RCO Net	RCO Net	RCO Net
	X-40 Gnd	X-40 Gnd	X-40 Gnd
	MSN (VHF)	MSN (VHF)	MSN (VHF)
	RSO Net	RSO Net	RSO Net
	TC-listen only	TC-listen only	TC-listen only
	Range Safety Mobile	Range Safety Mobile	Range Safety Mobile
Range Safety Mobile	Range Safety Mobile	Range Safety Mobile	Range Safety Mobile
	ATC (UHF)	**MSN (UHF)**	MSN (UHF)
	X-40 Gnd	**MSN (VHF)**	**X-40 Gnd**
Tower	Standard	**MSN (UHF)**	MSN (UHF)
Sport	Standard	**MSN (UHF)**	MSN (UHF)

X-40 Gnd - CH 1 or 3

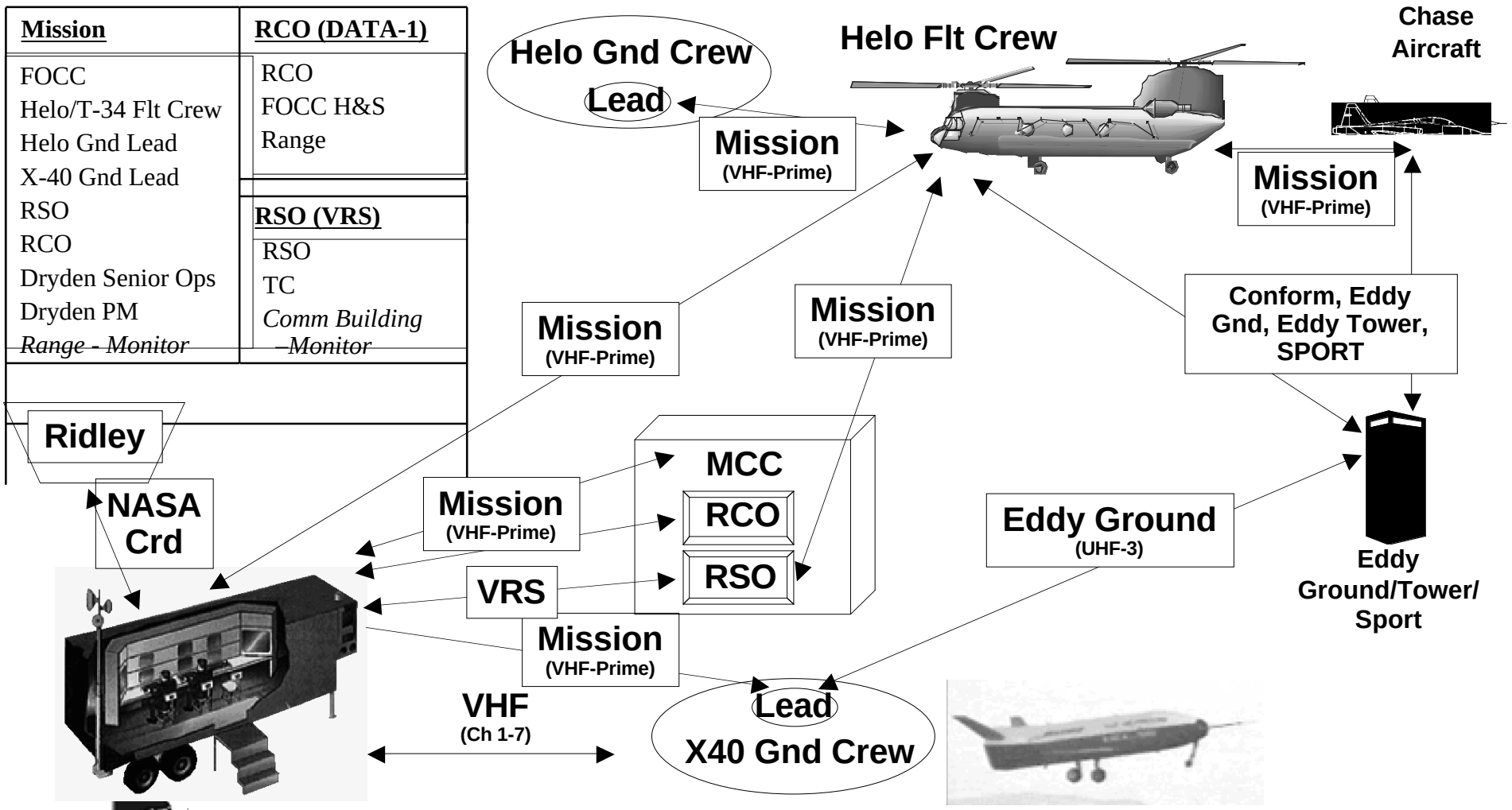
MSN (VHF) - 134.25

MSN (UHF) - 347.1

Communication Net

COMM CHANNELS

Mission	RCO (DATA-1)
FOCC Helo/T-34 Flt Crew Helo Gnd Lead X-40 Gnd Lead RSO RCO Dryden Senior Ops Dryden PM ~~*Range - Monitor*~~	RCO FOCC H&S Range
	RSO (VRS)
	RSO TC *Comm Building* ~~*–Monitor*~~



GO/NO GO - Takeoff

- **WX:**
  - No significant clouds below 15,500 ft agl
  - No visible precipitation in work area
  - Turbulence - pilot discretion
  - Sfc Winds < 20 kts (gusts and steady state)
  - Altitude Winds
    - Wind Shear $\leq$ 20 knots per 1000 ft below 2500-ft AGL
    - Average (integrated) magnitudes
      - $\leq$ 19 knots for Headwind
      - $\leq$ 36 knots for Tailwind
      - $\leq$ 26 knots for Crosswind
    - Or placarded magnitudes as shown in flight rules

GO/NO GO - Release

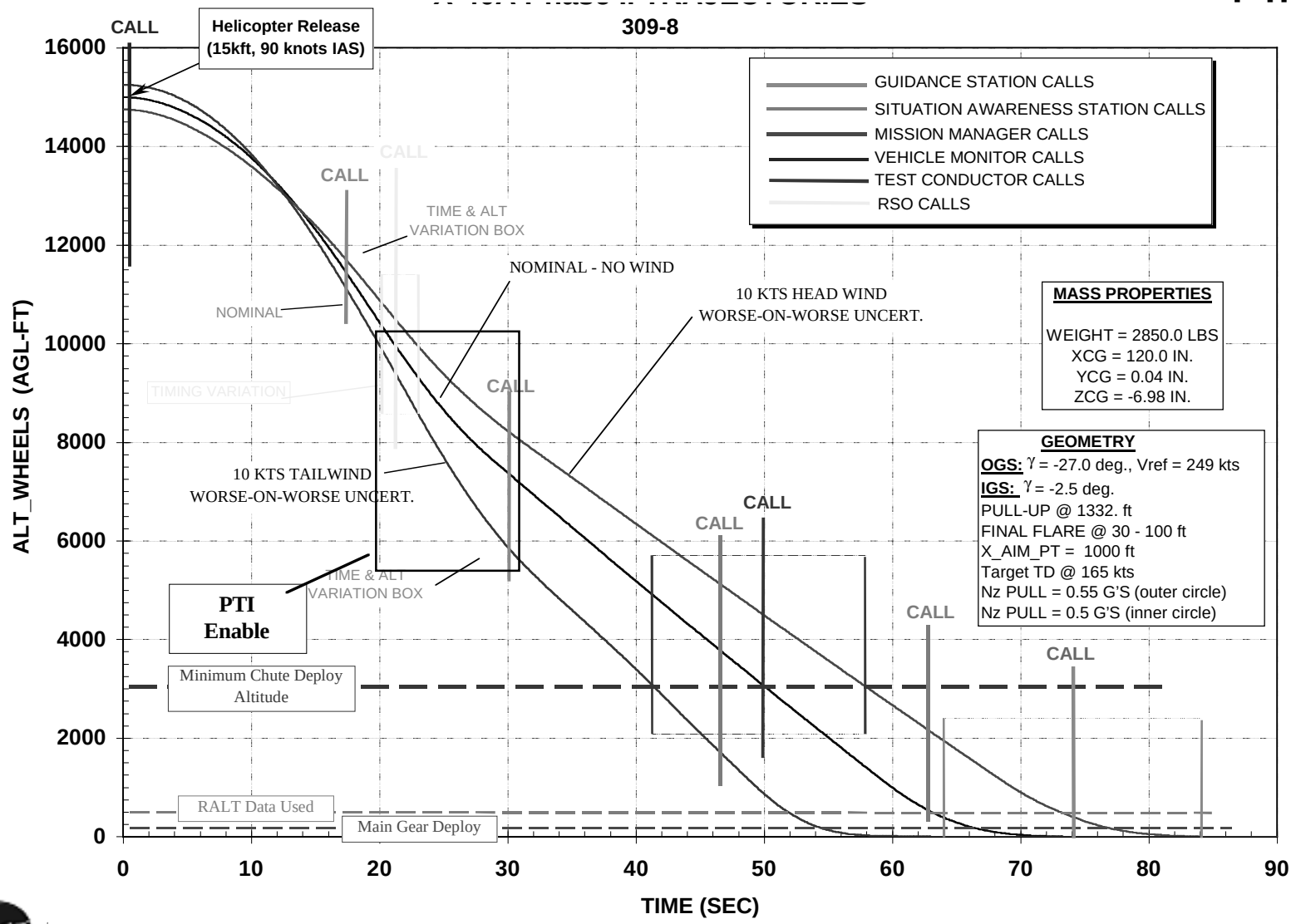
- **Same wind requirements**
- **RSO - GO (rwy clear, FTS Healthy)**
- **GNC-GO (Nav, Guidance, Flight Control Screens)**
- **The Release Box**
  - ± 300 ft downrange
  - ± 300 ft cross range
  - ± 250 alt

	Mean	3-sigma
EAS (knots)	**90**	± 5.0
Heading wrt RW (deg)	**0**	± 6.0
Angle-of-Attack (deg)	**-3**	± 3.0
Angle of Sideslip (deg)	**0**	± 6.0
Roll Angle (deg)	**0**	± 6.0
Pitch Rate (deg/s)	**0**	± 4.0
Roll Rate (deg/s)	**0**	± 6.0
Yaw Rate (deg/s)	**0**	± 4.0

C-MIGITS II vs. RAJPO Comparisons (in Runway Coordinate System)

	Mean	3-sigma
Delta X (ft)	**0**	± 40.0
Delta Y (ft)	**0**	± 40.0
Delta Z (ft)	**0**	± 60.0
Delta Vx (ft/s)	**0**	± 1.0
Delta Vy (ft/s)	**0**	± 1.0
Delta Vz (ft/s)	**0**	± 1.0

Flight Profile



Actions during the flight

Time from Release	Flight Condition	FOCC Comm Script	Comments
t - 1 min	‹ Xrw~7 mi. to threshold ‹ On CL & Altitude ‹ EAS=90 knots	‹ TC: ÒI minute; Hot passÓ	‹ TC: Minimize but continue coaching Helo toward release point (RP)
t - 30 sec	‹ Xrw~5.8 mi to threshold	‹ TC: Ò30 seconds; Hot passÓ ‹ TC:ÓRSO, GO/NO-GO CALLÓ ‹ MM: ÒStart RecorderÓ ‹ V.MON: ÒRecorder startedÓ ‹ MM: ÒCheck systems for GoÓ ‹ MM: ÒNavÓ; NAV: ÒGOÓ ‹ MM: ÒGuidanceÓ; GUID: ÒGOÓ ‹ MM: ÒFlt ControlÓ; FC: ÒGOÓ ‹ MM: ÒV.MONÓ; V.MON: ÒGO; Z count disconnectedÓ ‹ MM: ÒEX.MONÓ; EX.MON: ÒGOÓ	‹ Team: Assess all systems for ÒGOÓ ‹ V.MON: Uplink ÒMsg 3606 disconnectÓ
t - 20 sec	‹ Xrw~5.5 mi to threshold	‹ TC: Ò20 secondsÓ ‹ MM to TC: ÒGO for ReleaseÓ	‹ TC: Cease coaching Helo ‹ Team: Continue to assess all systems for ÒGOÓ
t - 10 sec	‹ Xrw~5.1 mi to threshold (2000 ft from RP)	‹ TC: Ò10 secondsÓ	‹ Team: Continue to assess all systems for ÒGOÓ
t - 5 sec	‹ Xrw~4.9 mi to threshold (1000 ft from RP)	‹ TC: ÒRelease on my mark: 5, 4, 1, É Ó	‹ MM: Quick scan of all screens ‹ TC: Start countdown
t ± 0	‹ Xrw=24,800 ft (± 350 ft)	‹ TC to Helo: ÒReleaseÓ ‹ from Helo: ÒVehicle awayÓ ‹ V.MON: ÒAUTOÓ(call on TC channel) ‹ from Chase: ÒClean ReleaseÓ	‹ FOCC Comm ONLY - all other commÕs OFF ‹ BNA team monitors flight performance ‹ TC monitors flight corridorÕs Redlines
t + 16 sec (±1 sec)	‹ Closed Loop Guidance ‹ H~21,500 ft AGL	‹ GUID: ÒClosed Loop Guidance, Go PTIÓ ‹ MM: ÒUplink PTIÓ	
t + 29 sec (±2 sec)	‹ Steep Glideslope Tracking ‹ H~7,700 ft AGL	‹ GUID: ÒSteep Glideslope; Low/Nominal/High Energy Ó	

Actions during the flight

Time from Release	Flight Condition	FOCC Comm Script	Comments
t + 30 sec (±2 sec)	⟨ H~7,500 ft AGL	⟨ RSO: "Option Command Sent"	⟨ For first flight wind placards only
t + 43 sec (±7 sec)	⟨ Steep Glideslope Tracking ⟨ H~4,000 ft AGL	⟨ V.MON: "Good Radar" ⟨ NAV: "Radar Confirmed"	
t + 48 sec (±2 sec)	⟨ H=3500 ft AGL	⟨ TC: "3500 ft"	⟨ Minimum chute altitude
t + 63 sec (±10 sec)	⟨ H=500 ft AGL	⟨ TC: "Arm Gear"	⟨ Call at 500 ft AGL
t + 67 sec (±10 sec)	⟨ H=150 ft AGL	⟨ VRS: "Gear Deployed" ⟨ V.MON: "Gear Down" ⟨ TC: "Landing Gear Switch OFF"	⟨ VRS deploys Landing Gear via VRS and holds switch ON until rollout
t + 74 sec (±10 sec)	⟨ Touchdown ⟨ Xrw ~ 1000 ft ⟨ EAS ~ 165 knots	⟨ GUID: "TOUCHDOWN; Low/Nominal/High"	⟨ GUID: Assess TD energy (Xnorm)
t + 76 sec	⟨ Nose gear touchdown ⟨ Xrw ~ 1,400 ft ⟨ GS ~ 150 knots	⟨ GUID: "Nose Gear Touchdown"	⟨ TC counts up X distance (in feet) ⟨ MM counts down EAS (in knots)
t + 84 sec	⟨ Braking ⟨ Xrw 3,700 ft ⟨ GS ~ 130 knots	⟨ V.MON: "Braking" ⟨ GUID: "Good Decel, Tracking Centerline"	
t + 116 sec	⟨ Wheel stop ⟨ Xrw ~ 8000 ft	⟨ MM: "Wheel stop; Mission complete" ⟨ V.MON: Uplink "Mission Complete" ⟨ TC: "Landing Gear Switch OFF"	⟨ V.MON uplinks "Mission Complete" ⟨ TC takes over Comm and executes Post-flight procedures

Contingency Plan

EP1

X-40A EMERGENCY RELEASE PROCEDURE

1. PILOT: CALL "**EMERGENCY RELEASE IMMINENT**" ON UHF AND INTERCOM

2. PILOT: ATTEMPT TO AVOID RELEASE OVER BUILDINGS, ROADS, OR STRUCTURES

3. PILOT: CALL "**RELEASE-RELEASE-RELEASE**" ON UHF AND INTERCOM

4. FTE: ROTATE ARM SWITCH TO "**ON**"

5. FTE: RAISE FIRING SWITCH COVER

6. FTE: MOVE FIRING SWITCH TO "**ON**"

7. FE: CONFIRM RELEASE, MONITOR STRONGBACK MOTION

8. PILOT: MONITOR RELEASE ON HOLE CAM, CALL "**GOOD/BAD RELEASE**" ON UHF AND INTERCOM

9. FTE: MOVE FIRING SWITCH TO "**OFF**"

10. FTE: LOWER FIRING SWITCH COVER

11. FTE: ROTATE ARM SWITCH TO "**OFF**"

12. PILOT: IF ABLE, VISUALLY TRACK X-40A THROUGH IMPACT AND COORDINATE WITH FLT ON MISSION **134.25 (122.85)**

EP2

X-40A PICKLE PROCEDURE

*****WARNING*****

EXECUTING THIS PROCEDURE WILL RESULT IN TOTAL LOSS OF X-40A VEHICLE

1. PILOT: CALL "**PICKLE-PICKLE-PICKLE**" ON MISSION AND INTERCOM

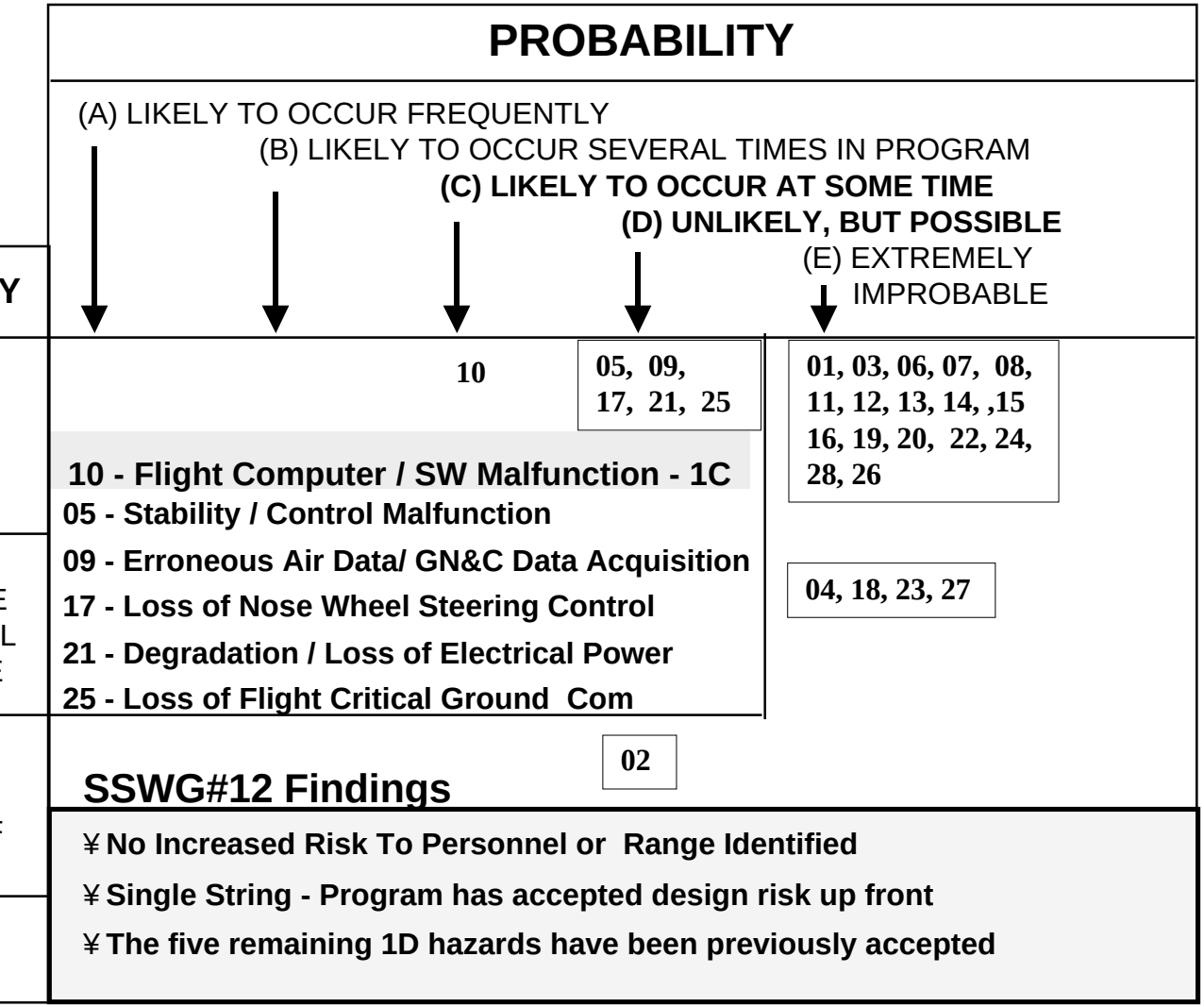
2. PILOT: DEPRESS CARGO HOOK EMERGENCY RELEASE BUTTON, MONITOR RELEASE ON HOLE CAM IF POSSIBLE

3. FE: CONFIRM RELEASE

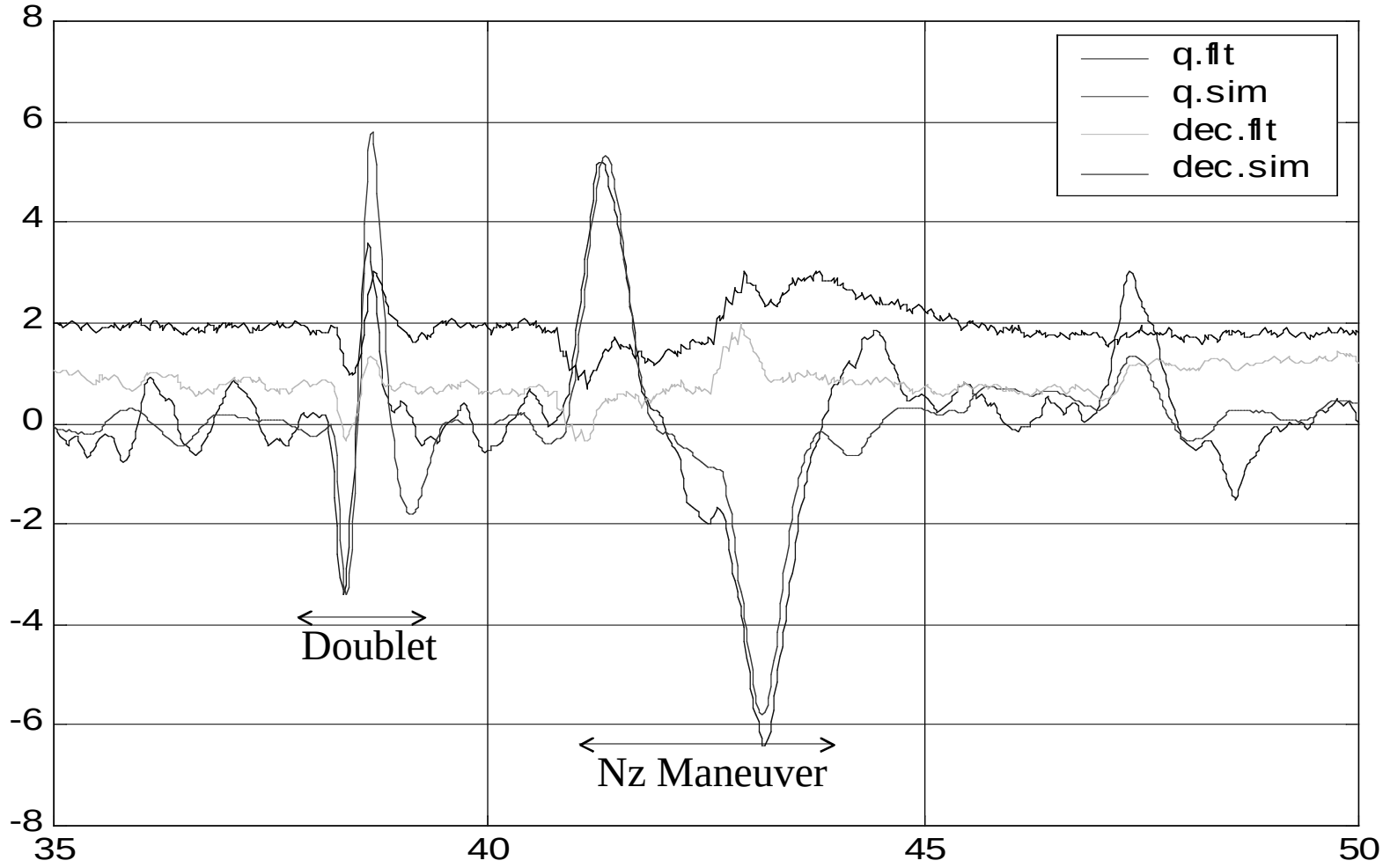
4. PILOT: CALL "**GOOD/BAD RELEASE**" ON UHF AND INTERCOM

5. PILOT: IF ABLE, VISUALLY TRACK X-40A THROUGH IMPACT AND COORDINATE WITH FLT ON MISSION **134.25 (122.85)**

Hazards Analysis

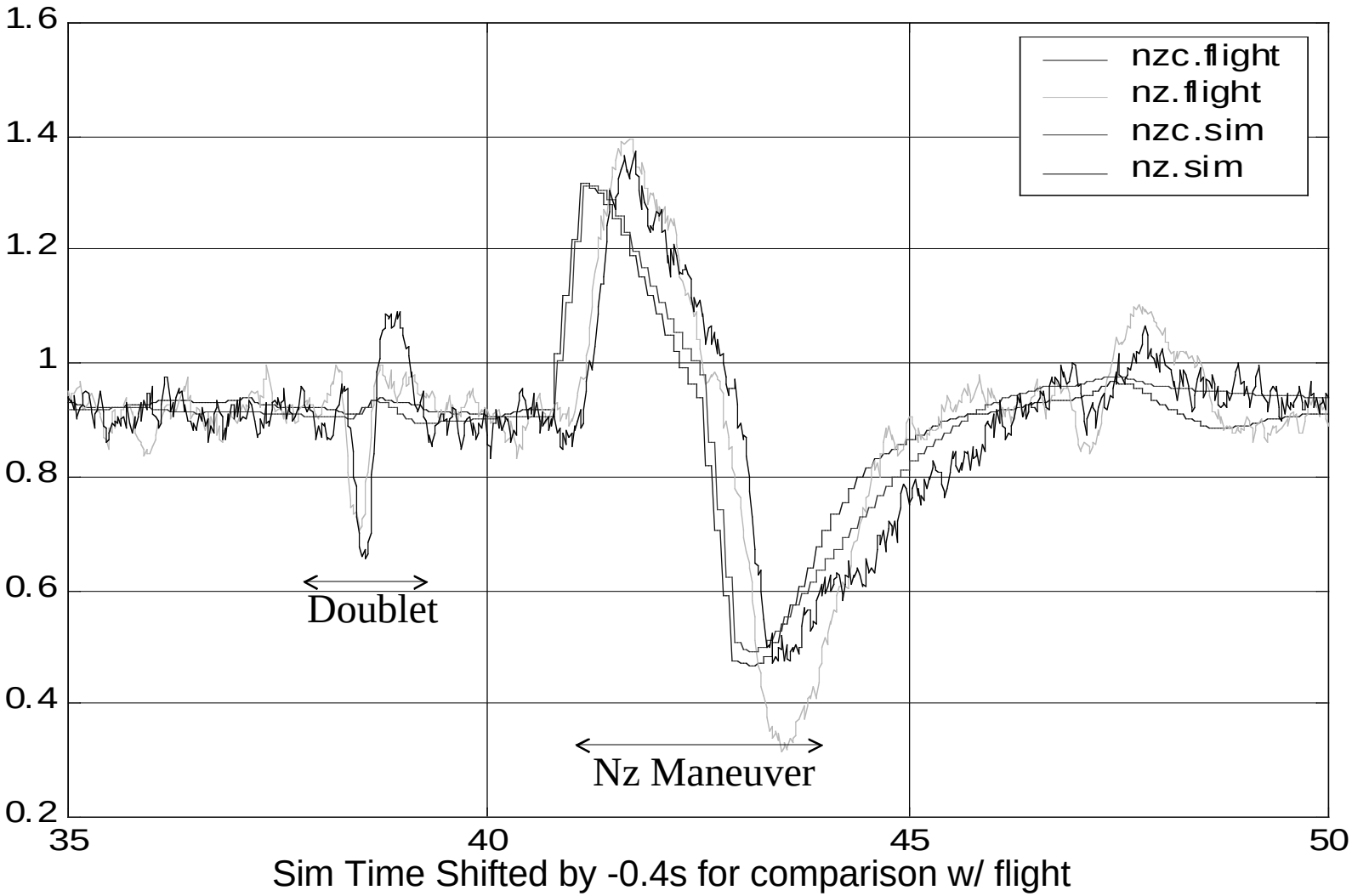


Flight #5 Data: Lon PID - Elev Doublet

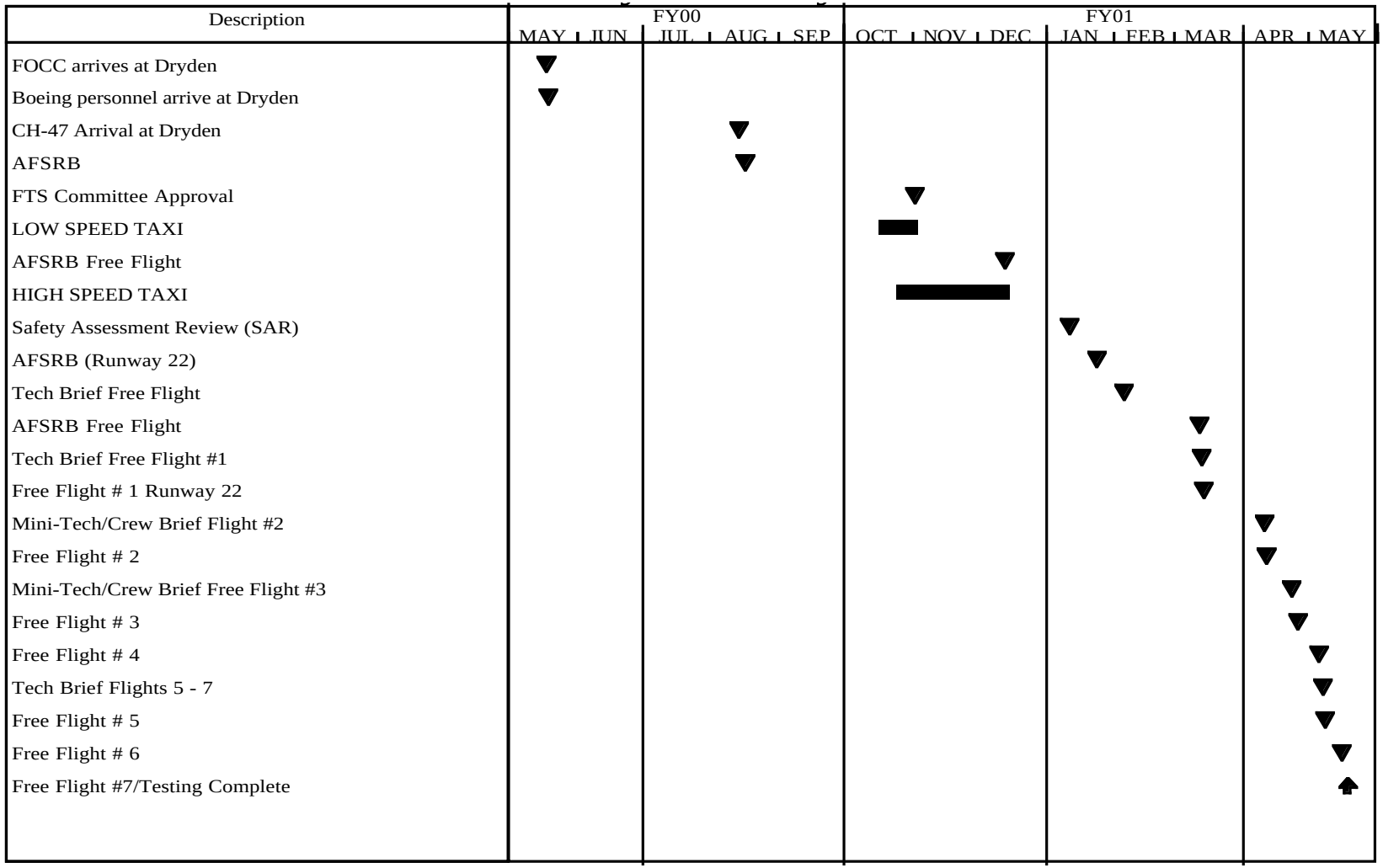


Sim Time Shifted by -0.4s for comparison w/ flight

Flight #5 Data: Lon PID - Nz Maneuver



Flight Test Schedule



Successful Flight Test Program

- **Completed 7 flights as originally planned**
- **No safety related incidents or mishaps**
- **No significant anomalies seen during flight testing**
  - GN&C system performance was outstanding
  - Aerodynamic data matches predictions well
  - Avionics suite performed as expected
- **Flight Data obtained is being used to refine the X-37 vehicle design**